- Fusion has safety advantages. Only a small quantity of fuel is located in the reaction chamber at any time. If a malfunction were to occur, any inadvertent release of energy and fuel would also be small.
- Advanced fusion reactors may be able to use only deuterium or other nonradioactive materials as fuel.

For these reasons, although the demonstration of economical power generation from fusion is perhaps one of the most difficult scientific endeavors ever undertaken, nuclear fusion offers great promise to become part of the long-term solution to the world's need for energy.

How Is Fusion Power Produced?

In addition to the three common states of matter—solid, liquid, and gaseous—there is a fourth state called a "plasma." At high enough temperatures, matter is ionized; that is, the electrons of its atoms are stripped away from the nuclei. The resulting mixture of electrons and atomic nuclei is known as a plasma. The nuclei, or ions, carry a positive electrical charge, and the electrons carry a negative electrical charge.

The charged particles in a plasma interact with magnetic fields in a way that causes them to rotate around magnetic field lines, much as iron filings are drawn into patterns by a magnet. Particles can move freely along magnetic field lines, traveling in a spiral, or helix, through a magnetic field. With careful design, it is possible to create "magnetic bottles," or config urations, that can effectively confine plasmas.

One of the most efficient mag netic configurations is a doughnut shape, or torus. Most magnetic confinement research today is focused on a toroidal configuration called the tokamak, invented in Russia in the 1950s. The name "tokamak" is derived from the Russian words for "torus," "chamber," and "magnetic."

The magnetic fields that confine the plasma in a tokamak are generated by powerful electro magnets, as shown below. By care fully adjusting the currents in these electromagnets, fusion scientists can control the plasma in the proper configuration.

Tokamaks have come the closest to simultaneously achieving the con ditions under which fusion fuel will react and produce significant energy. These conditions, which have been met individually, are as follows.

- The fusion fuel must be heated to very high temperatures. The tem perature needed for the fusion of deuterium and tritium is about 100 million degrees Celsius. At this temperature, the reacting particles have enough energy to overcome the electrostatic repulsion between particles with the same charge, so they can come close enough to fuse.
- The plasma must be dense enough (that is, the number of particles in the fusion plasma must be high enough) for significant power to be produced.
- The fuel must be contained so that it holds its energy long enough for the fusion reactions to occur and a net release of energy to take place.

Intensive programs in the areas of plasma physics and fusion tech nology have demonstrated the scientific feasibility of fusion. Current efforts are directed toward a combined demonstration of fusion's scientific and technological feasibility. Design studies are directed toward developing power plants that will produce electricity economically, reliably, and safely.

As with most scientific endeavors, the greatest challenges hold the greatest promise. Fusion research, with its goal of producing abundant energy to meet human needs, is one of the most chal lenging—and potentially most rewarding—areas of research today.